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Title of Invention

DC POWER SOURCE DEVICE

TECHNICAL FIELD

This invention relates to a DC power source device, in particular of the type for supplying necessary minimum drive current to a reference voltage source under the low output voltage condition such as the overloaded condition, and reducing the power consumption in the standby condition such as under the unloaded or light-loaded condition.

BACKGROUND OF THE INVENTION

Recently, energy saving in all electric products has been proposed in view of environmental protection, and in particular, it has become an important problem that recent power source devices should require reduction in power consumption during the standby condition. In addition, with increase of mobile electric equipments such as cellular phones late years, power source devices are necessary which have a chargeable battery and are safe under any loaded condition including an abnormal condition.

A prior art DC power source device shown in Figure 6 comprises a primary winding 3 of a transformer 2 and a switching element or MOS-FET 5 connected in series to a DC power supply 1; a rectifying smoother 6 connected to a secondary winding 4 of transformer 2 for supplying DC output power to a load 50; and a control circuit 9 for controlling turning-on and -off of MOS-FET 5 in response to the level of DC output supplied to load 50. Rectifying smoother 6 comprises a rectifying diode 7 connected to secondary winding 4 and a smoothing capacitor 8 connected to rectifying diode 7 to

supply DC output to load 50 through DC output terminals 29 and 30.

Control circuit 9 comprises a voltage stabilizer 10 for producing control signals of constant or regulated voltage to control the on-off period of MOS-FET 5 in order to make DC output voltage V_O to load 50 stabilize to a constant value V_2 ; a current controller 11 for producing current control signals to control the on-off period of MOS-FET 5 in order to make DC output current I_O settle on a constant value when DC output current I_O supplied to load 50 exceeds a rated value $I_{O\text{MAX}}$; a shunt regulator 24 as a reference voltage generator for producing a reference voltage V_{REF} ; a light emitter 26 of a photo-coupler 25 driven by logical sum signals of each output from voltage stabilizer 10 and current controller 11 for radiating a light output; a light receiver 27 of photo-coupler 25 for passing therethrough electric current the amount of which changes in proportion to an amount of light output radiated from light emitter 26; and a PWM controller 28 for supplying a gate terminal of MOS-FET 5 with drive signals V_G of variable pulse width in response to the amount of electric current through light receiver 27 of photo-coupler 25. Shunt regulator 24 is driven by output current I_{SH} from rectifying smoother 6 supplied through a bias resistor 23 to produce a reference voltage V_{REF} for regulating a reference value of output voltage V_O . Shunt regulator 24 may comprise, for example, a well-known IC (integrated circuit) for reference voltage such as TL431. Resistance value of bias resistor 23 is determined to supply shunt regulator 24 with drive current I_{SH} of a necessary minimum value when DC output voltage V_O is of the constant value V_2 . PWM controller 28 produces drive signals V_G of wide and narrow pulse width when respectively small and large amount of electric current flows through light receiver 27 of photo-coupler 25.

Voltage stabilizer 10 comprises detective resistors 12 and 13

connected between output terminals of rectifying smoother 6 for dividing DC output voltage V_O to load 50 into a desirable step-down level; and a voltage-controlling operational amplifier 14 which has an inverted input terminal for receiving a first divided voltage on a first junction between detective resistors 12 and 13 and a non-inverted input terminal for receiving a reference voltage V_{REF} of shunt regulator 24. Voltage-controlling operational amplifier 14 compares divided voltage on junction between detective resistors 12 and 13 and reference voltage V_{REF} of shunt regulator 24 to produce an error voltage between the divided and reference voltages as a control signal for constant voltage. Output terminal of voltage-controlling operational amplifier 14 is connected to light emitter 26 through a resistor 15 and a diode 16. Current controller 11 comprises a current detecting resistor 17 as an output current detection means connected to a negative output line of rectifying smoother 6 for detecting DC output current I_O through load 50 as a voltage corresponding to output current I_O ; parting resistors 18 and 19 connected to two terminals of shunt regulator 24 for dividing reference voltage V_{REF} from shunt regulator 24 into a second divided voltage on second junction between parting resistors 18 and 19 so that the second divided voltage provides a reference voltage V_{R1} for regulating the rated current value I_{OMAX} ; and a current-controlling operational amplifier 20 which has a non-inverted terminal for receiving detection signals from current detecting resistor 17 and an inverted terminal for receiving reference voltage V_{R1} on second junction between parting resistors 18 and 19. Output terminal of current-controlling operational amplifier 20 is connected to light emitter 26 through a resistor 21 and a diode 22. Current-controlling operational amplifier 20 compares detection signal from current detecting resistor 17 and reference voltage V_{R1} to produce an error voltage therebetween as a constant current control signal. Voltage control

operational amplifier 14 produces control signals for constant voltage which thereby causes electric current to flow through a resistor 15, a diode 16 and light emitter 26. Current control operational amplifier 20 produces control signals for constant current which thereby causes electric current to flow through a resistor 21, a diode 22 and light emitter 26. Optical output signals from light emitter 26 of photo-coupler 25 are controlled by a composite logical sum signal formed by constant voltage-current control signals from voltage and current control operational amplifiers 14 and 20.

Light emitter 26 of photo-coupler 25 produces a light output which is received by light receiver 27 to control electric current flowing through light receiver 27 to be proportional to an amount of light output from light emitter 26. PWM controller 28 modulates the pulse width of drive signals V_G based on a value of electric current flowing through light receiver 27 of photo-coupler 25 and provides gate terminal of MOS-FET 5 with the pulse width-modulated drive signal V_G . Resistors 15, 21, diodes 16, 22, photo-coupler 25 and PWM controller 28 form a drive signal generator. In this way, control circuit 9 controls the on-off period of MOS-FET 5 in response to DC output voltage V_O and DC output current I_O supplied to load 50 to always supply such stabilized DC output to load 50.

In operation of the DC power source device shown in Figure 6, PWM controller 28 of control circuit 9 forwards drive signals V_G to gate terminal of MOS-FET 5 to alternately turn MOS-FET 5 on and off so that DC input voltage is applied from DC power supply 1 to primary winding 3 of transformer 2 and MOS-FET 5 to cause electric current of high frequency to run through primary winding 3 and MOS-FET 5. Electric current of high frequency through primary winding 3 induces on secondary winding 4 high

frequency voltage which is then rectified and smoothed by rectifying diode 7 and smoothing capacitor 8 of rectifying smoother 6, and converted into DC output voltage V_O to load 50 through DC output terminals 29, 30.

When DC output current I_O equal to or less than a rated value I_{OMAX} is supplied to load 50 through DC output terminals 29 and 30, voltage stabilizer 10 of control circuit 9 operates to control DC output voltage V_O toward load 50 to a constant value V_2 as shown by a solid line A in Figure 7. Under such a normal operating condition, DC output voltage V_O between DC output terminals 29 and 30 is split to first junction voltage between detective resistors 12 and 13 so that voltage control operational amplifier 14 compares first junction voltage on the inverted input terminal with reference voltage V_{REF} on the non-inverted input terminal from shunt regulator 24 to generate an error voltage between these compared voltages from output terminal of voltage control operational amplifier 14. Accordingly, when first junction voltage divided from DC output voltage V_O is lower than reference voltage V_{REF} from shunt regulator 24, voltage control operational amplifier 14 produces a positive error voltage to reduce an amount of light output from light emitter 26 of photo-coupler 25, decreasing electric current through light receiver 27. With declination of electric current through light receiver 27, PWM controller 28 operates to widen on-pulse width or time span of drive signals V_G and provide them for MOS-FET 5 which therefore is turned on for a longer time. To the contrary, when first junction voltage of DC output voltage V_O is greater than reference voltage V_{REF} from shunt regulator 24, PWM controller 28 performs an opposite operation from the above-mentioned to shorten the on-period of MOS-FET 5. Thus, as shown by solid line A, DC output voltage V_O can be adjusted toward a constant value V_2 to supply load 50 with DC output power of constant voltage through DC output terminals 29

and 30.

In case DC output current I_o through load 50 is greater than rated value V_{OMAX} as in the overloaded condition, current control circuit 11 of control circuit 9 operates to control DC output current I_o to the constant rated value I_{OMAX} as shown by solid line B in Figure 7. Here, as DC output current I_o toward load 50 flows through detecting resistor 17 which picks out DC output current I_o as a corresponding voltage value thereto. On the other hand, parting resistors 18 and 19 split reference voltage V_{REF} from shunt regulator 24 to produce on second junction between parting resistors 18 and 19 reference voltage V_{R1} used to regulate DC output current I_o toward the rated value I_{OMAX} . Sensed voltage by detecting resistor 17 is input to inverted input terminal of current control operational amplifier 20 which compares sensed voltage from detecting resistor 17 with reference voltage V_{R1} on non-inverted terminal of operational amplifier 20 from second junction between parting resistors 18 and 19 so that operational amplifier 20 produces an error voltage between sensed voltage and reference voltage V_{R1} from output terminal. Error voltage from output terminal of operational amplifier 20 provides a control signal for constant current which flows through light emitter 26, diode 22 and resistor 21 to form a logical sum signal in cooperation with a control signal for constant voltage produced from voltage control operational amplifier 14. Accordingly, when DC output current I_o toward load 50 exceeds the rated value I_{OMAX} so that detection voltage by detecting resistor 17 is above reference voltage V_{R1} on second junction between parting resistors 18 and 19, current control operational amplifier 20 generates a negative error voltage to reduce the on-period of MOS-FET 5. Consequently, DC output voltage V_o rapidly drops while DC output current I_o through load 50 is maintained on a constant level I_{OMAX} as

shown by solid line B in Figure 7, indicating the constant current output characteristics. A typical example of such a DC power source device is disclosed by Japanese Patent No. 3,099,763.

Meanwhile, DC power source device shown in Figure 6 is defective in that it cannot supply shunt regulator 24 with minimum drive current I_{SH} necessary to keep reference voltage V_{REF} on a constant level when DC output voltage V_O declines to a lower voltage V_1 because resistance value of bias resistor 23 is determined to supply shunt regulator 24 with drive current I_{SH} of a necessary minimum value when DC output voltage V_O is on the constant value V_2 . As a result, when DC output voltage V_O drops as shown by solid line B in Figure 7, shunt regulator 24 fluctuates reference voltage V_{REF} , and therefore, disadvantageously changes DC output current I_O . On the contrary, if bias resistor 23 is set to a low resistance value to supply shunt regulator 24 with drive current I_{SH} of necessary minimum value when DC output voltage V_O falls to lower voltage V_1 , a large electric current runs through bias resistor 23 when DC output voltage V_O is of constant value V_2 , thereby inconveniently causing increase in power loss across bias resistor 23. As power loss across bias resistor 23 is indicated by seeking the square of potential difference between voltages V_1 and V_2 and then dividing the square by resistance value of bias resistor 23, the power loss increases with the greater difference between voltages V_1 and V_2 . During the load standby mode such as under the unloaded or light-loaded condition, the power source device increases the ratio of power loss across bias resistor 23 to the whole power loss so that increased power loss with bias resistor 23 is a serious hindrance against improvement in conversion efficiency during the load standby mode. In this manner, control circuit 9 unfavorably and rapidly increases a rate of consumed power in the load standby mode.

It is therefore an object of the present invention to provide a DC power source device which supplies a reference voltage source with necessary minimum drive current in case of the lowered output voltage, and controls drive current for the reference voltage source to a necessary minimum level in case of the rated output to reduce electric power consumed by the control circuit in the load standby mode such as under unloaded or light-loaded condition.

SUMMARY OF THE INVENTION

The DC power source device according to the present invention comprises at least one switching element (5) which performs the intermittent switching operation for converting DC input from a DC power supply (1) into high frequency electric power; a control circuit (9) for turning switching element (5) on and off; and a rectifying smoother (6) for converting the high frequency electric power through switching element (5) into a DC power output supplied to a load (50). Control circuit (9) comprises an output current controller (11) for controlling the on-off term of switching element (5) to make DC output current (I_o) through load (50) settle toward a rated value (I_{OMAX}); a reference voltage source (24) for receiving drive current (I_{SH}) supplied from rectifying smoother (6) and producing a reference voltage (V_{R1}) to regulate the rated value (I_{OMAX}) of output current controller (11); and a drive current controller (31) for keeping the drive current (I_{SH}) through the reference voltage source (24) on a substantially constant level under the rated output condition and the reduced output voltage condition. Therefore, drive current controller (31) functions to supply reference voltage source (24) with minimum drive current (I_{SH}) to maintain reference voltage (V_{REF}) on a constant level under the reduced output voltage, and also to control drive

current (I_{SH}) toward reference voltage source (24) to a necessary but minimum level in case of the rated output, thus, reducing power consumption in control circuit (9) during the load standby mode such as under the unloaded or light-loaded condition.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an electric circuit diagram showing a first embodiment of the DC power source device according to the present invention.

Figure 2 is an electric circuit diagram showing a second embodiment of the present invention.

Figure 3 is an electric circuit diagram showing a third embodiment of the present invention.

Figure 4 is an electric circuit diagram showing a fourth embodiment of the present invention.

Figure 5 is an electric circuit diagram showing a fifth embodiment of the present invention.

Figure 6 is an electric circuit diagram showing a prior art DC power source device.

Figure 7 is a graph showing an output drooping characteristics of DC power source device.

BEST MODE FOR CARRYING OUT THE INVENTION

Embodiments of the DC power source device according to the present invention are described with reference to Figures 1 to 5. Same symbols are applied to denote same elements in these Figures as those shown in Figure 6, and description thereon is omitted.

Each embodiment according to the present invention shown in Figures 1 to 5 is different from the prior art DC power source device shown

in Figure 6 in that each of the embodiments strikingly includes a drive current controller 31 in DC power source device for supplying a shunt regulator 24 with substantially constant drive current I_{SH} from rectifying smoother 6. In a first embodiment shown in Figure 1, in lieu of bias resistor 23 shown in Figure 6, a constant current source 32 as a drive current controller 31 is connected between DC output positive terminal 29 of rectifying smoother 6 and cathode terminal of shunt regulator 24. Drive current controller 31 is operated by output current I_{SH} from rectifying smoother 6 to always produce a constant current output regardless of voltage level V_O of DC output from rectifying smoother 6. Constant current source 32 may be selected from for example a current mirror circuit and a constant current circuit of bipolar transistors or MOS-FETs. If constant current output from constant current source 32 is adjusted to a necessary minimum current value to keep reference voltage V_{REF} from shunt regulator 24 on a constant level, constant current source 32 can always provide a constant current output for shunt regulator 24 independently from DC output voltage level V_O from rectifying smoother 6. Consequently, constant current source 32 furnishes shunt regulator 24 with a substantially constant drive current I_{SH} in the rated output and reduced voltage output conditions shown by respectively solid lines A and B in Figure 7. In other words, drive current controller 31 can, not only, provide shunt regulator 24 with minimum drive current I_{SH} necessary to maintain reference voltage V_{REF} from shunt regulator 24 on a constant level in case of the lowered output voltage, but also control drive current I_{SH} to shunt regulator 24 to a minimum but necessary level in case of the rated output. Accordingly, drive current controller 31 can minimize or keep constant power loss by drive current I_{SH} through shunt regulator 24, thereby causing control circuit 9 to reduce power consumption in the load standby mode such as under the unloaded or light-

loaded condition.

A second embodiment of the invention shown in Figure 2 comprises a drive current controller 31 connected between bias resistor 23 and cathode terminal of shunt regulator 24 shown in Figure 6. Drive current controller 31 comprises detecting resistors 33, 34 as an output voltage detector for dividing output voltage to detect DC output voltage V_o from rectifying smoother 6; a drive current control comparator 35 as a voltage comparing means which has an inverted input terminal for receiving a voltage divided by detecting resistors 33, 34 and a non-inverted input terminal for receiving reference voltage V_{REF} of shunt regulator 24 as a threshold voltage; and a current adjuster 36 which comprises a diode 37 as a rectifying element and a resistor 38 connected in series between an output terminal of control comparator 35 and cathode terminal of shunt regulator 24. Control comparator 35 produces first and second output signals of low and high voltage levels L and H when a voltage divided by detecting resistors 33, 34 is respectively higher and lower than reference voltage V_{REF} of shunt regulator 24. Current adjuster 36 is designed to supply shunt regulator 24 with only drive current I_{SH} from rectifying smoother 6 when control comparator 35 produces output signal of low voltage level, and otherwise to supply auxiliary drive current I_1 for shunt regulator 24 through diode 37 and resistor 38 in addition to drive current I_{SH} when control comparator 35 produces a different output signal of high voltage level.

When DC output voltage V_o from rectifying smoother 6 is controlled at the rated constant value V_2 as shown by solid line A of Figure 7, voltage divided by detecting resistors 33, 34 is higher than reference voltage V_{REF} of shunt regulator 24 so that control comparator 35 produces output signal of

low voltage level L . This turns diode 37 of current adjuster 36 off to supply drive current I_{SH} alone from rectifying smoother 6 through bias resistor 23 toward shunt regulator 24. When DC output voltage V_O from rectifying smoother 6 rapidly drops to or less than a level V_1 so that voltage divided by detecting resistors 33, 34 is lower than reference voltage V_{REF} of shunt regulator 24 as shown by solid line B of Figure 7, control comparator 35 produces an output signal of high voltage level H to turn diode 37 on so that auxiliary drive current I_1 flows from control comparator 35, diode 37, resistor 38, and then is added or superimposed on drive current I_{SH} from rectifying smoother 6 through bias resistor 23 to form a merger of drive current I_{SH} and auxiliary drive current I_1 through shunt regulator 24. Accordingly, if the sum of drive current I_{SH} and auxiliary drive current I_1 produced when diode 37 is in the on or conductive condition is equal to a value of drive current I_{SH} flowing through bias resistor 23 from rectifying smoother 6 when diode 37 is in the off or non-conductive condition, a substantially constant drive current I_{SH} can flow through shunt regulator 24 from rectifying smoother 6 throughout the rated output and reduced output voltage conditions shown by solid lines A and B of Figure 7.

In the embodiment shown in Figure 2, sufficiently high resistance value of bias resistor 23 can minimize power loss in shunt regulator 24 under the rated output condition. Also, the sum of drive current I_{SH} from rectifying smoother 6 through bias resistor 23 and auxiliary drive current I_1 from control comparator 35 through diode 37 and resistor 38 under the reduced output voltage condition, can provide shunt regulator 24 with minimum drive current I_{SH} necessary to maintain reference voltage V_{REF} of shunt regulator 24 on a constant level. Therefore, the embodiment of Figure 2 can accomplish minimized power loss in shunt regulator 24 by drive current I_{SH} , and

diminish power consumption in control circuit 9 in the load standby mode such as under unloaded or light-loaded condition.

Figure 3 represents a third embodiment according to the present invention which includes a drive current controller 31 connected between bias resistor 23 and cathode terminal of shunt regulator 24. Drive current controller 31 comprises detecting resistors 33, 34 for detecting DC output voltage V_O from rectifying smoother 6; a control comparator 35; and a current adjuster 36. Control comparator 35 has a non-inverted input terminal for receiving a divided voltage from detecting resistors 33 and 34, and an inverted terminal for receiving a reference voltage V_{REF} from shunt regulator 24 so that control comparator 35 produces output signals of high and low voltage levels H and L when divided voltage by detecting resistors 33, 34 is respectively higher and lower than reference voltage V_{REF} from shunt regulator 24. Current adjuster 36 comprises a first series connection circuit of a PNP transistor 39 as a switch means and a resistor 40 connected to both ends of bias resistor 23, and a diode 37 as a reverse current inhibitor and a resistor 38 connected in series between an output terminal of control comparator 35 and a base terminal of PNP transistor 39. When control comparator 35 produces output signals of high voltage level H, PNP transistor 39 is turned off to supply shunt regulator 24 with drive current I_{SH} alone from rectifying smoother 6 through resistor 23, adversely when control comparator 35 produces output signals of low voltage level L, PNP transistor 39 is turned on to supply shunt regulator 24 with auxiliary drive current I_1 through resistor 40 in addition to drive current I_{SH} through resistor 23 to superimpose auxiliary drive current I_1 on drive current I_{SH} .

When DC output voltage V_O from rectifying smoother 6 is controlled

to the rated constant value V_2 shown by solid line A of Figure 7, voltage divided by detecting resistors 33, 34 is higher than reference voltage V_{REF} of shunt regulator 24 so that control comparator 35 produces an output signal of high voltage level H. At this moment, diode 37 of current adjuster 36 is biased in the adverse direction to the off or non-conductive mode, and PNP transistor 39 is turned off due to the signal of high voltage level H applied on base terminal of PNP transistor 39 to supply drive current I_{SH} alone from rectifying smoother 6 through bias resistor 23 toward shunt regulator 24. Then, when DC output voltage V_O from rectifying smoother 6 rapidly drops to or less than a level V_1 so that voltage divided by detecting resistors 33, 34 is lower than reference voltage V_{REF} of shunt regulator 24 as shown by solid line B of Figure 7, control comparator 35 produces an output signal of low voltage level L to bias diode 37 in the forward direction to the on or conductive condition, thereby causing PNP transistor 39 to be turned on with base current going through base terminal of PNP transistor 39. Accordingly, under the reduced output voltage condition, auxiliary drive current I_1 flows from rectifying smoother 6 through PNP transistor 39 and resistor 40 to merge into drive current I_{SH} from rectifying smoother 6 through bias resistor 23 to form a sum or united drive current through shunt regulator 24. Accordingly, if the sum of drive current I_{SH} through bias resistor 23 and auxiliary drive current I_1 through PNP transistor 39 and resistor 40 when PNP transistor 39 is in the conductive condition, is equal to a value of drive current I_{SH} flowing through bias resistor 23 from rectifying smoother 6 when PNP transistor 39 is in the non-conductive condition, a substantially constant drive current I_{SH} can flow through shunt regulator 24 from rectifying smoother 6 throughout the rated output and reduced output voltage conditions shown by solid lines A and B of Figure 7.

Similarly to the embodiment shown in Figure 2, sufficiently high resistance value of bias resistor 23 can minimize power loss through shunt regulator 24 under the rated output condition. Also, the sum of drive current I_{SH} from rectifying smoother 6 through bias resistor 23 and auxiliary drive current I_1 through PNP transistor 39 and resistor 40 in the reduced output voltage condition, can provide shunt regulator 24 with minimum drive current I_{SH} necessary to maintain reference voltage V_{REF} of shunt regulator 24 on a constant level as in Figure 2. Therefore, the embodiment in Figure 3 can accomplish minimized power loss in shunt regulator 24 by drive current I_{SH} , and diminish power consumption in control circuit 9 in the load standby mode such as under the unloaded or light-loaded condition.

A DC power source device of an embodiment shown in Figure 4 comprises a second control comparator 43, a second diode 44 and a second resistor 45 connected in series between a junction of detecting resistors 33, 34 and cathode terminal of shunt regulator 24. Also, connected between cathode terminal of shunt regulator 24 and non-inverted input terminal of second control comparator 43 are dividing resistors 41 and 42 which divide reference voltage V_{REF} from shunt regulator 24 to produce a reference voltage V_{R2} . Second control comparator 43 has an inverted input terminal connected to junction of detecting resistors 33 and 34, and a non-inverted input terminal of second control comparator 43 from junction of dividing resistors 41 and 42 as a threshold voltage for second control comparator 43. Reference voltage V_{R2} on junction of dividing resistors 41 and 42 is set to a value lower than reference voltage V_{REF} from shunt regulator 24.

Under the rated output condition where DC output voltage V_O from rectifying smoother 6 is controlled to a constant value V_2 shown by solid line

A of Figure 7, voltage divided by detecting resistors 33, 34 is higher than reference voltage V_{REF} of shunt regulator 24 and reference voltage V_{R2} on junction of dividing resistors 41 and 42 so that first and second control comparators 35 and 43 produce output signals of low voltage level L. At this moment, both diodes 37 and 44 of current adjuster 36 are biased in the adverse direction to the off or non-conductive mode to supply drive current I_{SH} alone from rectifying smoother 6 through bias resistor 23 to shunt regulator 24.

Then, when DC output voltage V_O from rectifying smoother 6 rapidly drops to or less than a level V_1 as shown by solid line B of Figure 7 so that divided voltage on junction of detecting resistors 33, 34 comes to a value between reference voltage V_{REF} of shunt regulator 24 and reference voltage V_{R2} on junction of dividing resistors 41 and 42, first control comparator 35 produces an output signal of high voltage level H to bias diode 37 in the forward direction to the on or conductive condition, and second control comparator 43 produces an output signal of low voltage level L to bias diode 44 in the reverse direction to the off or non-conductive condition. Here, a first auxiliary drive current I_1 flows from first control comparator 35 through diode 37 and resistor 38 to join with drive current I_{SH} flowing from rectifying smoother 6 through bias resistor 23 into a merged drive current through shunt regulator 24. When DC output voltage V_O from rectifying smoother 6 further falls beneath level V_1 so that divided voltage on junction of detecting resistors 33, 34 descends under reference voltage V_{R2} on junction of dividing resistors 41 and 42, each of first and second control comparators 35 and 43 produces an output signal of high voltage level H to bias diodes 37 and 44 in the forward direction to the on or conductive condition. Accordingly, first and second auxiliary drive currents I_1 and I_2 flow from first control comparator

35 through diode 37 and resistor 38 and from second control comparator 43 through diode 44 and resistor 45 to join with drive current I_{SH} flowing from rectifying smoother 6 through bias resistor 23 into a merged drive current through shunt regulator 24.

In this way, embodiment shown in Figure 4 enables two stage change in auxiliary drive current by separately adding auxiliary drive current I_1 only or I_1 plus I_2 through diodes 37 and 44 and resistors 38 and 45 of current adjuster 36 to drive current I_{SH} through shunt regulator 24 in response to voltage level on junction of detecting resistors 33 and 34, thereby resulting in accurate adjustment of drive current to shunt regulator 24 in response to drop of DC output voltage V_O from rectifying smoother 6.

Now referring to Figure 5, a fifth embodiment according to the present invention is shown which comprises a plurality of switch means, namely a second series connection circuit of a PNP transistor 46 and a resistor 47 connected in parallel to first series connection circuit of PNP transistor 39 and resistor 40; and a further series circuit of a control comparator 43, a diode 44 and a resistor 45 connected between junction of detecting resistors 33 and 34 and base terminal of PNP transistor 46. Dividing resistors 41 and 42 are connected between a cathode terminal of shunt regulator 24 and inverted input terminal of second control comparator 43 to produce a reference voltage V_{R2} on junction between dividing resistors 41 and 42 by dividing reference voltage V_{REF} from shunt regulator 24. Similarly to the embodiment shown in Figure 4, reference voltage V_{R2} on junction between dividing resistors 41 and 42 is set to a value lower than reference voltage V_{REF} from shunt regulator 24. Junction of detecting resistors 33 and 34 is connected to non-inverted terminal of second control

comparator 43 whose inverted terminal is connected to junction between dividing resistors 41 and 42.

Under the rated output condition where DC output voltage V_O from rectifying smoother 6 is controlled to a constant value V_2 shown by solid line A of Figure 7, voltage divided by detecting resistors 33, 34 is higher than reference voltage V_{REF} of shunt regulator 24 and reference voltage V_{R2} on junction of dividing resistors 41 and 42 so that first and second control comparators 35 and 43 produce output signals of low voltage level L. At this moment, both diodes 37 and 44 of current adjuster 36 are biased in the adverse direction to the off or non-conductive mode to supply drive current I_{SH} alone from rectifying smoother 6 through bias resistor 23 to shunt regulator 24.

Then, when DC output voltage V_O from rectifying smoother 6 rapidly drops to or less than a level V_1 as shown by solid line B of Figure 7 so that divided voltage on junction of detecting resistors 33, 34 comes to a value between reference voltage V_{REF} of shunt regulator 24 and reference voltage V_{R2} on junction of dividing resistors 41 and 42, first control comparator 35 produces an output signal of low voltage level L to bias diode 37 in the forward direction to the on or conductive condition, and second control comparator 43 produces an output signal of high voltage level H to bias diode 44 in the reverse direction to the off or non-conductive condition. As low voltage signal is applied to base terminal of PNP transistor 39, first PNP transistor 39 only is turned on to pass first auxiliary drive current I_1 from rectifying smoother 6 through PNP transistor 39 and resistor 40, and first auxiliary drive current I_1 joins with drive current I_{SH} flowing from rectifying smoother 6 through bias resistor 23 into a merged drive current through

shunt regulator 24. When DC output voltage V_O from rectifying smoother 6 further falls beneath level V_1 so that divided voltage on junction of detecting resistors 33, 34 descends under reference voltage V_{R2} on junction of dividing resistors 41 and 42, each of first and second control comparators 35 and 43 produces an output signal of low voltage level L to bias diodes 37 and 44 in the forward direction to the on or conductive condition, thereby causing first and second PNP transistors 39 and 46 to be turned on. Accordingly, first and second auxiliary drive currents I_1 and I_2 flow from rectifying smoother 6 through PNP transistors 39 and 46, resistors 40 and 47 to both join with drive current I_{SH} flowing from rectifying smoother 6 through bias resistor 23 into a merged drive current through shunt regulator 24.

In this way, the embodiment shown in Figure 5 enables two stage change in auxiliary drive current by turning on one or both of PNP transistors 39 and 46 of current adjuster 36 in response to voltage level on junction of detecting resistors 33 and 34 to separately add to drive current I_{SH} through shunt regulator 24, auxiliary drive current I_1 only or I_1 plus I_2 through PNP transistors 39 and 46 and resistors 40 and 47 of current adjuster 36, thereby resulting in accurate adjustment of drive current through shunt regulator 24 in response to drop of DC output voltage V_O from rectifying smoother 6.

The foregoing embodiments should not restrict the present invention and may be further modified in various ways. For example, in lieu of shunt regulator 24 of reference voltage IC as a reference voltage generator, a typical Zener diode may be used to perform similar functions and take similar effects. Also, Figures 4 and 5 disclose the embodiments each which comprises two control comparators 35 and 43 for two stage change of

auxiliary drive currents toward shunt regulator 24 in response to drop of DC output voltage V_o , however, they may comprise three or more control comparators for more accurate multistage change of auxiliary drive currents for shunt regulator 24. Moreover, NPN transistors, p-channel or n-channel MOS-FETs may be used in place of PNP transistors 39 and 46 as switch means in the embodiments shown in Figures 3 and 5. In this case, non-inverted and inverted input terminals are adversely provided in control comparators 35 and 43 with diodes 37 and 44 of reversed polarity. Also, although the foregoing embodiments according to the present invention are applied to control circuits which indicate the constant current drooping characteristics as shown by solid line B of Figure 7, the present invention would be able to apply to control circuits which indicate the fold-back current or constant power drooping characteristics as shown by dotted line C or alternate long and short dash line D of Figure 7.

INDUSTRIAL APPLICABILITY

The DC power source device according to the present invention is applicable to DC-DC converters of flyback, forward, bridge, push-pull and current resonance types, an electrical isolation type which has a transformer with isolated input and output, non-isolated booster or step-down chopper type.